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CONE AND SEED YIELDS IN

YOUNG WESTERN WHITE PINES

R.T. Bingham and G. E. Rehfeldt

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EXPERIMENT STATION
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THE AUTHORS

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ABSTRACT

    Eighteen years of cone and seed yields from 179 30- to 50-year-old western white pines (*Pinus monticola* Dougl.) representative of 13 geographic localities were compared. Each tree averaged 28 cones per tree, and each cone contained about 104 filled seeds. However, not only was annual cone production highly variable, but geographic localities and individual trees varied greatly in productivity within a given year. Recognition of these components of variation in cone production for western white pine can lead to maximal efficiency in cone collection.
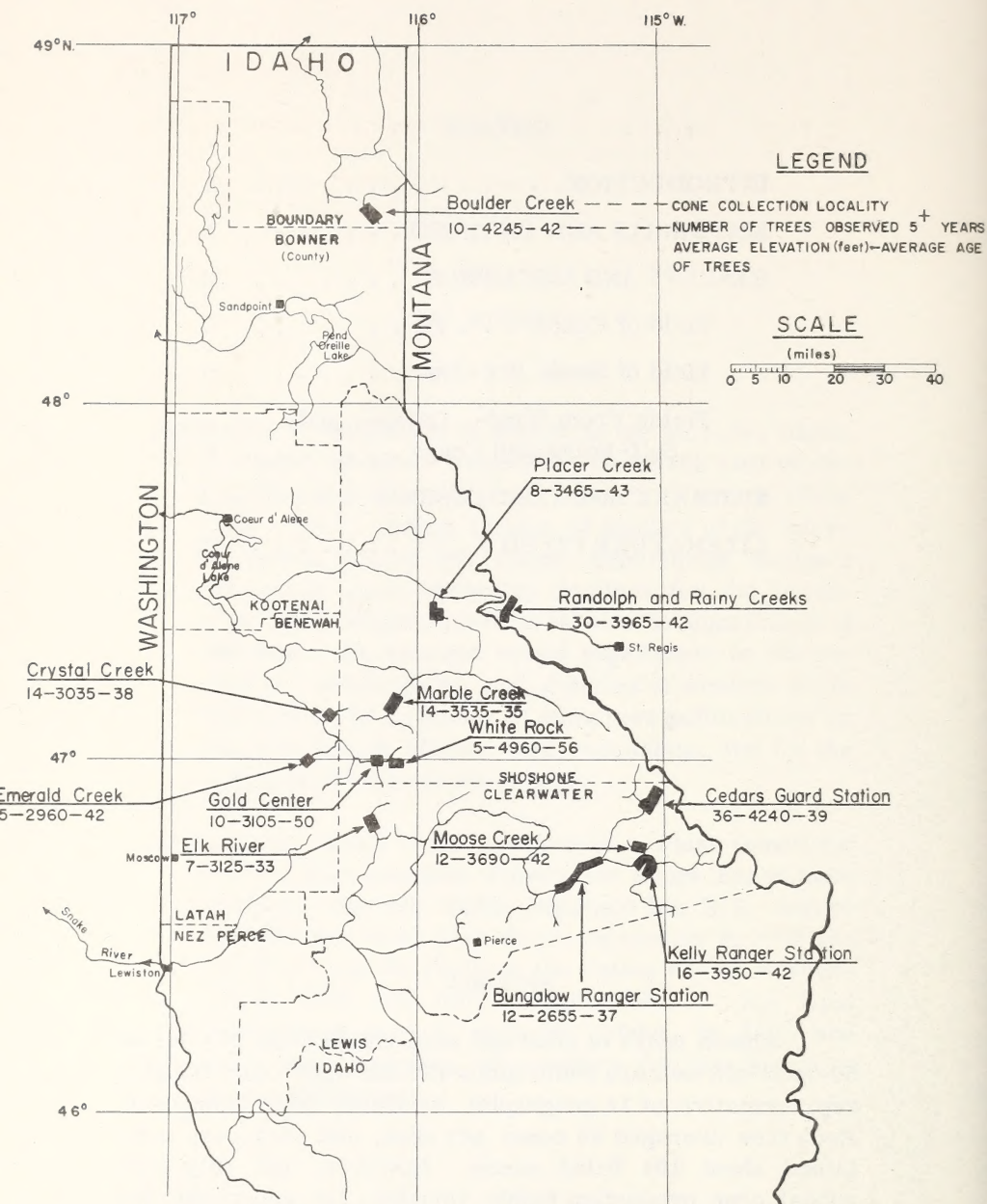
117°   116°   115° W.

49°N.

IDAHO

LEGEND

Boulder Creek ── ── ── CONE COLLECTION LOCALITY
10 – 4245 – 42 ── ── ── NUMBER OF TREES OBSERVED 5⁺ YEARS─
AVERAGE ELEVATION (feet)─AVERAGE AGE
OF TREES

BOUNDARY
BONNER
(County)

Sandpoint

MONTANA

Pend Oreille Lake

SCALE
(miles)
0   5   10   20   30   40

48°

Placer Creek
8 – 3465 – 43

WASHINGTON

Coeur d' Alene

Coeur d'Alene Lake

KOOTENAI
BENEWAH

Randolph and Rainy Creeks
30 – 3965 – 42

St. Regis

Crystal Creek
14 – 3035 – 38

Marble Creek
14 – 3535 – 35
White Rock
5 – 4960 – 56

47°

Emerald Creek
5 – 2960 – 42

Gold Center
10 – 3105 – 50

SHOSHONE
CLEARWATER

Cedars Guard Station
36 – 4240 – 39

Elk River
7 – 3125 – 33

Moscow

Moose Creek
12 – 3690 – 42

LATAH
NEZ PERCE

Snake River

Lewiston

Pierce

Kelly Ranger Station
16 – 3950 – 42

Bungalow Ranger Station
12 – 2655 – 37

LEWIS
IDAHO

46°

Figure 1.--*Map of northern Idaho illustrating the 13
geographic localities from which cones were collected
and the number, average elevation, and average age of
trees represented within each locality.*

INTRODUCTION

Forest managers normally recognize and anticipate periodicity in cone production of forest trees. However, variation in cone production among geographic localities and individual trees within localities is largely unexplored, for rarely are cones collected in consecutive years from the same trees.

In the course of breeding western white pine (*Pinus monticola* Dougl.) for resistance to blister rust (see Bingham, Olson, Becker, and others. 1969 and earlier), 18 years of data on cone and seed yields of individual trees from different geographic localities have been accumulated. The protection of cones during development minimized losses due to insects and rodents; therefore, these data simulate the full reproductive potential of young trees in natural stands. Annual variation in cone production among geographic localities and individual trees thus is represented in these data. This information is indispensable for practices of seed collection and seed orchard management which rely on knowledge relating to cone yields of individual trees and possibly on yields derived from controlled pollinations.

MATERIALS AND METHODS

During the years 1950 to 1967, cone and seed yields were obtained from 179 30- to 50-year-old western white pines. Trees were representative of 13 geographic localities (figure 1) within which they varied in elevation by about 400 feet; within two localities, however, trees differed in elevation by about 1500 feet.

Comparisons of yields between seed years, localities, and trees within localities were made on the basis of mean yield; statistical analyses were not attempted because yields for each maternal tree and locality were not available for each year. Criteria for including yields of individual trees in the basic data were: (1) five or more years of observation were

available; and (2) observations were for consecutive
or nearly consecutive years. Since periodicity in
cone production of western white pine tends to follow
3- and 4-year cycles,[1] yields for each tree were rep-
resented for nearly all stages of cyclic production.
It is therefore assumed that minimal confounding is
represented in the data.

RESULTS AND DISCUSSION

Yield of Cones

At tree ages of 30 to 50 years, annual production
of cones averaged about 28 per tree. This mean char-
acterizes cone production inadequately because yield
is subject to an interaction of exogenous and endogen-
ous factors. The interaction causes tremendous varia-
tion in cone production among seed years, geographic
localities, and maternal trees within each locality.

Within the 18-year period, mean yield of cones
for individual seed years differed by as much as 55
cones per tree (table 1). In fact, the mean yield of
cones per tree, in successive seed years, differed by
as much as 34 cones. These differences in yield among
seed years reflect a periodicity in cone production
which is documented elsewhere in greater detail.[1]

Mean yield for geographic localities over all
years of observation differed by as much as 64 cones
per tree (table 2). However, the degree of difference
between localities depended on the seed year. For
instance, in 1967 which was a year of high mean yield,
localities differed by as much as 78 cones per tree;
but in 1956 when few cones were produced, maximum dif-
ferences between localities were only 20 cones per
tree. Thus, differences in yield among localities
were evident, especially in years of high yield. Lo-
calities characterized by low cone yields, however,
produced few cones even in favorable seed years.

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[1]G. E. Rehfeldt, A. R. Stage, and R. T. Bingham.
Time series analysis for production of female strobili
in western white pine. Manuscript in preparation.

Table 1.—Mean yields of cones per tree according to the seed year and the localities with the lowest and highest mean yield for each year

| | Yields per year | | Yields per locality | | | |
| | | | Locality of lowest yield | | Locality of highest yield | |
Year	Trees observed	Mean (cones/tree)	Trees observed	Mean (cones/tree)	Trees observed	Mean (cones/tree)
1950	26	23.2	4	0	1	53.0
1951	29	27.8	4	2.0	12	50.6
1952	29	16.4	3	0	2	195.0
1953	38	18.2	5	0	5	74.4
1954	34	49.8	2	7.5	13	71.6
1955	7	40.8	1	22.0	1	55.0
1956	85	10.5	2	3.5	6	23.6
1957	11	16.5	1	5.0	5	27.0
1958	87	38.0	10	20.4	5	130.8
1959	87	28.3	31	18.5	4	159.5
1960	107	18.0	8	6.1	5	36.6
1961	146	21.8	3	3.3	9	60.9
1962	136	29.1	4	2.5	4	82.5
1963	119	25.3	4	0.8	9	86.2
1964	95	59.3	4	25.0	5	148.8
1965	91	40.3	2	28.5	5	84.0
1966	80	51.0	2	10.5	10	90.4
1967	76	65.3	3	21.0	10	99.0

Table 2.--Mean yields of cones per tree for each year according to the locality, and the tree within each locality with the highest and lowest mean yield

Locality	Trees observed	Mean years of observation	Mean (cones/tree/year)	Yield per tree			
				Tree of lowest yield		Tree of highest yield	
				Years observed	Mean (cones/year)	Years observed	Mean (cones/year)
Emerald Creek	5	6.8	4.6	9	3.7	6	7.5
Gold Center	10	8.0	15.2	7	2.8	8	33.8
Placer Creek	8	6.5	16.2	7	4.6	5	55.4
Cedars Guard Station	36	7.2	20.5	6	0	6	89.1
Bungalow Ranger Station	12	6.6	22.7	7	4.0	10	58.1
Rainy and Randolph Creeks	30	7.4	23.4	7	0.6	11	69.8
Moose Creek	12	6.2	23.6	6	11.0	7	29.4
Elk River	7	7.1	30.3	6	6.0	12	46.1
Kelly Ranger Station	16	5.6	42.7	5	10.6	5	73.6
Marble Creek	14	5.8	55.2	5	8.2	8	122.9
Crystal Creek	14	11.1	56.1	8	1.6	18	129.7
White Rock	5	11.0	63.0	9	19.9	9	87.2
Boulder Creek	10	5.2	68.5	5	15.2	5	114.2

BINGHAM, R.T. and G.E. REHFELDT

1970. Cone and seed yields in young western white pines. USDA
Forest Serv. Res. Pap. INT-79, 12 p.

Eighteen years of cone and seed yields from 179 30- to 50-year-old
western white pines (*Pinus monticola* Dougl.) representative of 13
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per tree, and each cone contained about 104 filled seeds. However,
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Cone yields also varied among individual trees
within localities (table 2). Differences in cone pro-
duction of individual trees within localities were
directly proportional to the effect of the seed year
just as were differences in yield among localities.
Moreover, differences in cone yield per year among
individual trees depended on the overall yield of the
locality. Although cone production by trees in high-
yielding localities differed by as much as 100 cones
per tree for each year, trees within localities of low
mean yield showed little difference in production.
Thus, each locality contained trees that characteris-
tically produced few cones, even in good seed years;
differences among localities apparently resulted from
varying proportions of trees that produced large crops
of cones in generally high-yielding years.

Of the exogenous factors that affect cone yield,
the one that cannot be assessed at this time, due to
lack of data, is the influence of microsites on the
yield of trees within localities. However, other
factors can be assessed; tree age, elevation, and
latitude can be related to mean cone yield by correla-
tion analyses (table 3). Although unequal sampling
and possible intercorrelations among age, elevation,

Table 3.--*Correlation of tree age, tree elevation, and*
locality latitude with cone yield of: individual
trees; trees within localities; and localities

Cone yield	Tree age	Tree elevation	Locality latitude	d.f.
	----*Correlation coefficient, r*----			
Individual trees	0.33**	0.42**	--	177
Trees within local- ities (pooled r)	.45**	.44**	--	166
Localities	--	--	.66*	11

**Significant at the 1 percent level of probability.
 *Significant at the 5 percent level of probability.

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and latitude make interpretation difficult, cone yield
per tree and locality appears weakly associated with
tree age and tree elevation. Significance of the in-
dicated correlation between cone yield of localities
and locality latitude is doubtful because values for
Boulder Creek (highest latitude and high elevation)
exert enough influence to inflate the correlation
coefficient over the 5 percent level of significance.

Yield of Seeds Per Cone

The average wind-pollinated cone yielded approxi-
mately 104 filled seeds; thus, each tree produced
nearly 3,000 filled seed per year. However, yields
of filled seeds per cone were positively associated
with the yield of cones (r = .79, significant at the
1 percent level of probability). Mean yield of filled
seeds per cone thus varied according to seed years
(table 4), localities (table 5), and trees within
localities (table 5). In fact, yields of seeds per
cone ranged from 25 to 149 for two trees in different
localities and in different seed years.

Exogenous variables cannot entirely account for
the tremendous variation in total number of filled seed
per tree. Tree 212 near Cedars Guard Station and tree
58 in the Crystal Creek area (see figure 1) outwardly
were similar in terms of age, size, dominance, and
local stand density (table 6). Although the cone yield
of tree 212 was about one-half that of tree 58, the
seed yield of 212 was less than one-fourth that of 58.
Possible genetic control of these traits requires
elucidation; their importance in seed orchards might
be great.

Yields From Wind-, Cross-, and
Self-Pollinated Cones

Statistical analyses (paired "t" tests) of balanced
samples of filled seeds per cone (table 7) indicate
that yields derived from self-pollinations were less
(1 percent level of probability) than those of wind-
or cross-pollinations; no differences were detected

Table 4.--Mean yields of filled seeds per cone according to the seed year and the localities with the lowest and highest mean yield for each year

| | Yields per year | | Yields per locality | | | |
| | | | Locality of lowest yield | | Locality of highest yield | |
Year	Trees observed	Mean (seeds/tree)	Trees observed	Mean (seeds/tree)	Trees observed	Mean (seeds/tree)
1950	17	77.3	3	28.0	1	156.0
1951	18	75.2	6	42.2	10	97.2
1952	8	77.5	6	72.0	2	94.0
1953	20	93.1	5	69.0	2	142.5
1954	25	149.5	3	114.3	11	164.1
1955	5	106.4	1	77.0	4	113.8
1956	14	82.6	4	75.8	4	88.7
1957	4	107.5	-	-	-	-
1958	17	124.2	5	106.2	2	177.5
1959	15	92.1	3	63.0	7	105.1
1960	8	61.0	2	50.0	4	62.5
1961	22	77.7	6	49.3	2	128.5
1962	32	94.4	2	41.5	3	151.3
1963	17	72.4	2	18.0	6	104.5
1964	18	130.5	1	37.0	1	147.0
1965	18	73.4	2	50.0	1	114.0
1966	21	98.7	2	61.5	2	123.0
1967	24	99.9	1	81.0	3	143.0

Table 5.--*Mean yields of filled seeds per cone according to the locality and tree within each locality with the highest and lowest mean yields*

Locality	Trees observed	Mean years of obser-vation	Mean (seeds/tree/year)	Yield per tree			
				Tree of lowest yield		Tree of highest yield	
				Years observed	Mean (seeds/year)	Years observed	Mean (seeds/year)
Gold Center	6	5.5	70.6	7	50.7	5	93.8
Rainy and Randolph Creeks	5	6.2	85.0	6	45.8	5	116.4
Cedars Guard Station	8	6.4	90.9	8	24.8	5	133.4
Crystal Creek	11	10.1	97.8	6	52.3	7	112.7
Marble Creek	3	5.3	102.2	6	91.2	5	123.6
White Rock	5	8.0	112.5	9	75.1	11	155.6
Elk River	3	7.0	119.0	6	95.3	6	149.5

Table 6.--*Variation in cones, seeds, and total seed yield of several low and high yielding trees*

Item	Low yielding trees Tree number					High yielding trees Tree number				
	134	35	37	183	212	266	20	109	54	58
Locality	Rainy and Randolph Creeks	Gold Center	Gold Center	Cedars G.S.	Cedars G.S.	Marble Creek	Crystal Creek	Marble Creek	White Rock	Crystal Creek
Age in 1967	52	52	56	43	52	28	50	44	60	50
Year measured	1956	1951	1951	1956	1956	1961	1952	1959	1952	1952
Height (feet)	50	49	64	33	60	34	68	62	55	60
Diameter breast high (inches)	8.5	11.6	11.3	6.0	19.6	9.9	13.1	16.5	13.5	11.7
Dominance class	Inter-med.	Dom.	Dom.	Dom.	Dom.	Dom.	Dom.	Dom.	Dom.	Dom.
Stand density	Med.-dense	Open	Med.-open	Open	Open	Open	Med.-open	Open	Med.	Open
Mean cones/year	10.1	10.4	12.4	14.4	52.6	75.1	96.1	122.9	74.5	114.7
Years cones observed	7	10	11	10	11	7	11	8	14	18
Mean filled seed/cone	45.8	50.7	63.8	81.5	24.8	123.6	111.7	91.2	155.6	112.7
Years yield observed	6	7	5	6	8	5	7	6	11	15
Mean total filled seed/year	463	527	791	1174	1304	9282	10,734	11,061	11,592	12,927

between yields of the latter two groups. Lowered seed
yields accompanying self-pollination in western white
pine is well documented (Bingham and Squillace 1955;
Squillace and Bingham 1958; Barnes, Bingham and Squillace
1962).

As noted previously (Bingham and Squillace 1955),
the yield of total seeds (filled plus hollow) was essen-
tially the same regardless of the type of pollination
(table 7). The large proportion of hollow seeds that
develop after self-pollination apparently result from
embryo abortion because full-sized hollow seeds failed to
develop following earlier failures in pollination, pollen
tube growth, or fertilization in *Pinus sylvestris* L.
(Sarvas 1962).

Table 7.--*Yield of filled and hollow seeds per cone from
wind-, cross-, and self-pollinations. Compari-
sons are based on yields from trees on which
observations were available in the same seed
years*

Comparisons			Pollen type	Yield of seeds per cone		
Group	Trees observed	Years observed		Filled	Hollow	Total
A	28	9	Wind	111.2	12.0	123.2
			Cross	102.7	21.4	124.1
			Self	60.9	57.4	118.3
B	40	11	Wind	102.1	13.7	115.8
			Cross	94.4	21.3	115.7
			Self	--	--	--
C	141	12	Wind	--	--	--
			Cross	95.4	22.9	118.3
			Self	51.8	58.6	110.4

Approximately one-third of all control-pollinated
cones, whether cross-or self-pollinated, failed to
reach maturity. Since losses of cones due to insects,
rodents, or breakage were known and minimal, losses
of control-pollinated cones were almost entirely due
to abortion of cones during development. Sarvas (1962)
suggested that conelet abortion in pines is associated
with high ovule abortion rates accompanying poor polli-
nation. Conelet abortion of pines also appears to be
associated with soil moisture stresses during the period
of conelet elongation in *P. monticola*[2] and *P. radiata*
D. Don (Pawsey 1960).

SUMMARY AND CONCLUSIONS

Between the ages of 30 and 50, western white pines
average 28 cones per year. Each cone contains about
104 filled seeds which means that each tree produces
about 3,000 filled seeds; however, tremendous variations
occur. Annual production of cones is highly variable.
Also, within a given seed year certain localities and
individual trees within localities vary greatly in
productivity. Of additional importance is the direct
relationship between the proportion of filled seed
and the size of the cone crop. Increased efficiency
in seed collection can be realized by avoidance of
low-yielding localities, trees and seed years. Also,
by collecting only in high-yielding localities, cone and
seed procurement can be maximized with a minimum of
effort. This is particularly true when cone production
is generally low.

It is further noteworthy that once techniques
are mastered and proper timing is ascertained, yields
derived from controlled pollinations of western white
pine almost equal those of wind pollination.

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[2] Ibid.

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Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field Research Work Units are maintained in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

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